



# Soil Quality Monitoring: A Practical Guide

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Soil quality is the foundation of sustainable crop production. While it is true that soil testing serves the purpose of monitoring soil; testing focuses mainly on the ability of the soil to provide plant nutrients; it doesn't serve the purpose of measuring overall soil quality. Soil quality assessment helps to determine the status of soil functions and environmental risks associated with production practices. Depending on what we do and how we treat our soil, we may improve or impair long-term soil health and productivity.

Soil quality cannot be measured directly. However, it can be assessed indirectly using indicators (also referred here soil properties) of soil condition on different scales in a given time frame. Soil has physical, chemical, and biological components. Indicators developed from these components should be measurable, simple, and sensitive to manage with intervention intended to bring an indicator or group of indicators to an acceptable level. Many soil quality indicators are vital to the proper function of the whole system. All indicators of soil quality must be at optimum levels for the system to work properly.

## How Does Soil Assessment Work?

### 1. Know reference or standard values of indicators

To assess the status of a given soil, one needs to be aware of standard values for indicators of optimal soil quality as determined by available data. Values can be point estimates or a range for a given soil or field. For example, the optimum levels of bulk density for sandy, silty, and clayey soils are <0.92, <0.81, and <0.64 oz/in<sup>3</sup>, respectively (Table 1). Any value greater than (farther than) the reference or standard value is considered undesirable. The use of indicator for soil quality assessment requires a good knowledge of the indicator. Some measured variables have optimum levels and any value higher or lower will be less than desirable. For example, pH values between 5.8 and 7.2 are acceptable for several field crops. High levels of organic carbon (C) and total nitrogen (N) in the soil are desirable; while lower values of sodium (Na) adsorption ratio (SAR) are preferable.

### 2. Scoring

There are different ways of scoring soil quality parameters. The scoring used here assigns a higher score to the value of a given soil condition (parameter) most suitable for plant growth and lower scores as values depart from the most suitable scenario or acceptable value. Criteria can be

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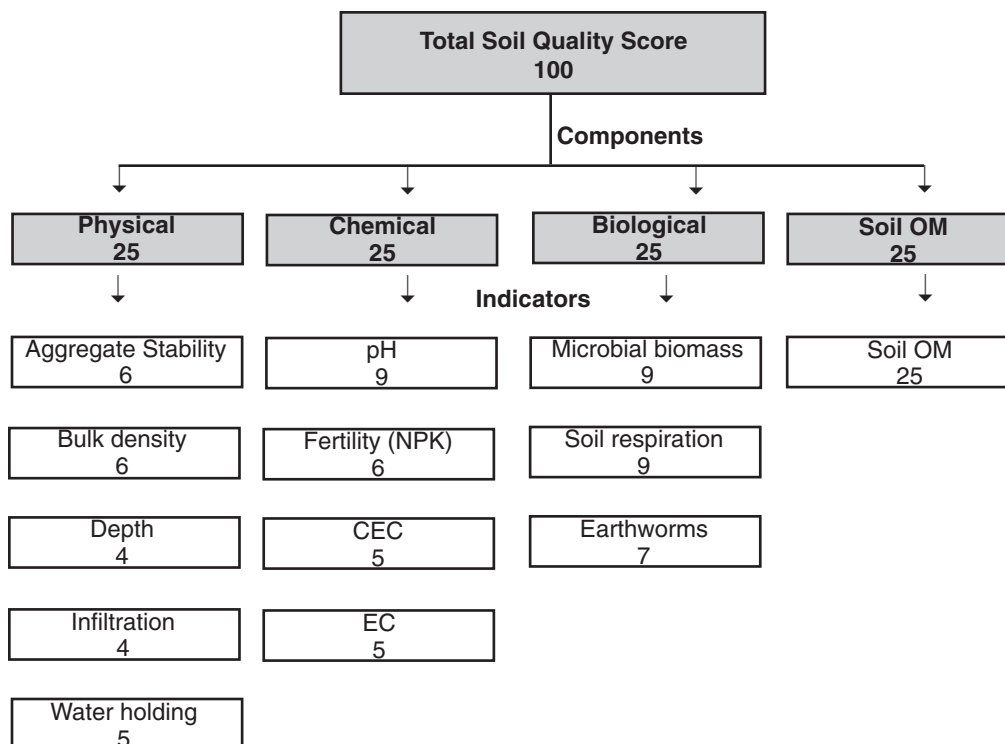
### General criteria for assigning scores to an indicator

- The component or indicator controls important soil ecosystem functions such as aeration, water infiltration/transmission, water retention, root proliferation, and nutrient supply.
- The component or indicator requires a unique intervention. This means to bring soil back to optimum level of a specific indicator, it requires specific intervention. Example, in a critically low pH soil, adding lime is needed to raise the pH quickly, instead of waiting for organic matter levels to rise and increase pH.
- An indicator can be easily measured (or estimated).
- An indicator can be assessed using qualitative and/or quantitative methods.
- An indicator can be estimated in a reasonable amount of time.

weighted according to the relative importance of a given indicator within a component and its relationship with other indicators. The maximum score for an overall soil quality is 100 (Figure 1). This is partitioned into physical, chemical, biological, and organic matter (OM) components. Each component is assigned a score of 25. Organic matter is treated as a separate component because of its importance in controlling overall soil health and the biological component always refers to the living beneficial macro and microorganisms in the soil and does not include the dead organic mass. Next, assign weighted scores to indicators based on importance. For example, within the chemical component, pH is a master variable and is assigned the maximum possible score. Other factors, such as electrical conductivity (EC) or NPK may be altered by changing pH; thus they are assigned lower scores. The total scores of selected indicators should add up to the component score. Indicators shouldn't be assigned a score of '0' since a soil cannot be totally nonfunctional.

### 3. Measuring soil property data from the field

The next step is to collect representative soil samples from a field for physical, chemical, and biological analysis. In



**Figure 1. Maximum possible scores for different soil components and soil quality indicators within a component.**

many cases representative samples collected for routine soil test suffice, particularly for soil chemical properties. This is killing two birds with one stone, as the information from the routine soil analysis can be used to assess the status of soil quality with minimal additional expense, although samples for quantifying soil physical and biological properties may require separate sampling and/or determination. Follow links provided in the ‘useful resources’ section to learn about soil sampling, soil physical properties, microbial biomass, and respiration determination.

#### 4. Applying the scoring system to assess soil quality level of a field

Once the producer has determined values reflecting the soil conditions, the next step is to assign score to the reported value of each indicator based on information presented in Table 1. Add the scores of indicators within a component to get an impression of which component is farther from the total score assigned for the component. Add the score for the components to get the total soil quality index. Use the matrix presented in Table 2 to determine the soil quality score of your field and the corresponding general recommendation.

#### 5. Intervention

Once the soil quality status is determined, the next step is to devise an intervention plan. Intervention varies with the soil type, crop and management history, and resources needed. If a component score is only 5 points lower than the total assigned score for a specific component or if the total score is >90 (Table 2), only minor intervention is needed. Intervention should start from the indicator with the lowest score within a component and should first involve a master variable such

as OM or pH. Intervention needs to be comprehensive and simultaneous within a given time frame. The intervention can involve adding several soil amendment practices at the same time or one after the other. However, addition of OM is the single most important practice that is effective to bring to optimum level many soil parameters simultaneously. Suggested intervention practices for each indicator are presented in the Appendix. Most practices will improve more than one soil quality indicator.

#### 6. Monitoring and Maintenance

Soil monitoring is very important for sustaining soil quality. It involves analyzing the soil through soil tests and field observations, and seeing how the soil changes after intervention. Once an intervention plan is implemented, it is necessary to monitor the change in the soil by measuring indicators. This requires seasonal/yearly sampling of soil and analyzing the parameters.

### Glossary of Soil Quality Indicator Terms

**Soil aggregate stability**—the resistance of soil particles held together in a cluster against external forces such as tillage and erosion.

#### Assumptions

- Intervention should be unique to a field, soil type and crops mostly produced on the field.
- The soil assessment and intervention is based on indicator values for typical arable annual crops including cereals and vegetables.

**Table 1. Assigning values and scores to three scenarios of soil quality indicators.**

<i>Indicator</i>	<i>Value and corresponding score (in parenthesis)</i>			<i>Remark</i>
	<i>Best</i>	<i>Good</i>	<i>Poor</i>	
OM, %	3.5-5 (25)	2.5-3.5 (20)	<2 (15)	
<b>Physical properties</b>				
Water stable aggregation, %	>80 (6)	60-80 (4)	50-60 (2)	
Bulk density (BD), oz/in <sup>3</sup>	<0.64, <0.81 & <0.92 (6)	0.64<BD<0.74, 0.81<BD<0.92 & 0.92 <BD<0.98 (3)	>0.81, >0.92 & >0.98 (1)	Clayey, silty & sandy soil, respectively
Depth, inch	>40 (4)	20-40 (3)	<20 (2)	Varies with crop
Infiltration rate, in/hr	0.4-2.0, 0.08-1.0 & 0.01-0.1 (4)	± 0.2 of best value (3)	± 0.4 of best value (2)	Sandy/silt, loam & clayey, respectively
Water holding capacity, in/24 in soil	2.4 & 3.5 (5)	1.6-2.4 & 3.5-3.9 (3)	<1.6 & >3.9 (1)	Not desirable if out of "good" range
<b>Chemical properties</b>				
pH	5.8-7.3 (9)	5.0-5.7, 7.3-8.0 (6)	<5, > 8 (3)	
Fertility ( N, P and K)	N-100% of yield goal P&K- 100% sufficient (6)	N-80% of yield goal P&K- 80% sufficient (4)	N-< 80% of yield goal P&K- < 80% sufficient (2)	Based on recommended rate for specific field and crop
CEC, meq/oz soil	14-25 (5)	5-14 (3)	<5 (1)	
EC, dS/m	<0.98 (5)	0.98 - 1.71 (3)	>1.71 (1)	Varies with crop
<b>Soil Biological Properties</b>				
Microbial biomass oz C/100 lbs soil	0.6-1.1 (9)	0.3-0.6 (6)	<0.3 (3)	4 in top soil
Soil respiration lbs CO <sub>2</sub> -C/a/d	32-64 (9)	16-32 (7)	<16, >64 (4)	4 in top soil
Earth worm, #/ft <sup>2</sup> in holes	> 15 (7)	5-15 (5)	<5 (3)	Population is limited by resource availability

**Table 2. Total soil quality score and corresponding general recommendation.**

<i>Total score</i>	<i>Intervention type</i>	<i>Description</i>
>90	Minor new intervention; continue with maintenance to avoid degradation	Look for the indicator with lowest score and intervene with appropriate remediation practices
80-90	Moderate intervention	Look for the indicator with lowest score for each component and intervene with appropriate remediation practices.
<80	Major and immediate intervention is required	Investigate the score of indicators in each component and apply comprehensive best management practices. This level of soil quality warrants the need for raising soil organic matter level.

**Soil bulk density (BD)**- the mass of dry soil per unit of volume.

**Infiltration rate** – the rate of downward entry of water into the soil.

**Water holding capacity**– the approximate amount of water a soil can retain following a precipitation or an irrigation incident.

**Soil pH**– the degree of acidity or alkalinity of a soil.

**Cation exchange capacity (CEC)** – the sum total of exchangeable cations that a soil can potentially adsorb. It indirectly influences soil fertility.

**Soil electrical conductivity (EC)** – the capacity of soil to conduct or transmit electrical current. EC is directly related to the amount of soluble salts in the soil.

**Soil respiration** – the microbial transformation of OM into CO<sub>2</sub> gas.

**Soil microbial biomass** – part of the organic matter in the soil that constitutes living microorganisms.

### Useful Resources

PSS-2207 How to Get a Good Soil Sample

PSS-2225 OSU Soil Test Interpretations

PSS-2257 Building Soil Organic Matter for a Sustainable Organic Crop Production

PSS-2226 Reclaiming Slick-Spots and Salty Soils

Soil Respiration-USDA NRCS

Guidelines for Soil Quality Assessment in Conservation Planning

**Appendix. Indicator and corresponding potential problems if the indicator is not at desirable level, causes and intervention required to return an indicator to a desirable level.**

<i>Soil Property/Indicator</i>	<i>Potential problems</i>	<i>Causes</i>	<i>Intervention</i>
OM	Low OM	Excess tillage, monocropping, residue burning, high harvest index and erosion	Diversify or increase crop rotations, use organic amendments, cover crops, high residue crops and adopt reduced tillage
Soil aggregate Stability	Crusting, erosion and poor infiltration	Low organic matter, compaction and low residue	Adopt conservation tillage, use organic amendments (animal manure, litter, biosolids, mulch, green manure etc), grow cover crops and retain residue cover on soil surface
Bulk Density	Compaction	Heavy traffic, poor aggregation and low soil OM	Avoid working wet soil, reduce traffic, adopt minimum tillage, add organic amendment and diversify cropping systems
Soil depth	Limited root expansion and drainage	Erosion, monocropping, intensive high biomass production and low soil OM	Reduce erosion, add organic amendments, retain crop residue and adopt conservation tillage
Infiltration rate	Poor infiltration	Lack of residue cover, low soil OM, excess Na, poor aggregation, heavy traffic and tillage pan	Diversify or increase crop rotations, add organic amendments, use cover crops and adopt conservation tillage
Water holding capacity	reduced root and plant growth, runoff and nutrient leaching	Low soil OM, conventional tillage, low residue cover, monocropping and heavy traffic	Adopt conservation tillage, crop rotation, cover crops, prescribed grazing and leach out salt
Soil pH	Acidity	Continuous use of inorganic N fertilizers and high harvest index with addition of lime	Add lime for low pH, improve drainage, add OM and add sulfur or alum to reduce pH
Fertility	Poor crop growth and reduced yield	Low soil OM, unbalanced pH, continuous cropping without rotation and reduced stubble return	Add fertilizer and organic amendments
CEC	Low nutrient reserve in the soil and variable pH	Low soil OM, leaching, erosion and high harvest index	Add organic amendments, use cover crops, retain crop residue and exercise crop rotation
EC	Salinity/sodicity	Saline seeps, Saline irrigation water, shallow water table, poor drainage and excess evaporation	Leach excess salts, plant deep rooted crops, grow salt tolerant crops, increase vegetative cover, manage irrigation water and improve drainage
Soil Microbial biomass Soil respiration	Reduced microbial activity in the soil	Low soil OM, high C:N ratio, and sub-optimal soil temperature, moisture and aeration	Agricultural practices that increase soil OM usually enhance soil respiration
Earth worms	Reduced nutrient cycling, impeded drainage and poor aggregate stability	Little or no organic residues in the soil, high/low soil temperature and moisture, and low soil OM	Agricultural practices that increase soil OM usually increase earthworm population

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